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DEPARTMENT OF SCIENCES
I SEMESTER M.Sc. (PHYSICS)
END SEMESTER REGULAR EXAMINATIONS, NOVEMBER & DECEMBER 2023
Quantum Mechanics - I [PHY 5153]
(CHOICE BASED CREDIT SYSTEM - 2020)

Time: 3 Hours | Date: 04/12/2023 | MAX. MARKS: 50

Note (i) Answer ALL questions

(ii) Draw diagrams, and write equations wherever necessary

Q No	Question	Marks	CO	BL
1A	Describe linear vector space. Give an example.	5	2	2
1B	Interpret expectation value of an operator in quantum mechanics.	3	3	5
1C	What conditions must the parameter ϵ and the operator $\hat{G}$ satisfy so that the operator $\hat{U} = e^{i\epsilon\hat{G}}$ is unitary?	2	2	4
2A	Explain the basic postulates of quantum mechanics.	5	3	4
2B	Show that $$\frac{d}{dt}\langle\hat{x}\rangle = \frac{1}{m}\langle\hat{p}\rangle.$$ Discuss the significance of the above equation.	3	3	3
2C	Define time evolution operator. Is the time evolution in quantum mechanics unitary? Justify.	2	3	1, 5
3A	Find the bound state wave function and the corresponding energy of a particle in a delta function potential well $V(x) = -\alpha\,\delta(x)$.	4	4	3
3B	The ground state ψ_0 of the 1D harmonic oscillator can be defined using the condition $$\hat{a}_{-}\psi_0 = 0\,.$$ Using the above condition, determine the normalized ground state wave function. Also, find the ground state energy. Given $$\hat{a}_{-} = \frac{1}{\sqrt{2\hbar m\omega}}(i\hat{p} + m\omega x)$$	4	4	3
3C	Compare the energies of 3D rectangular potential well and cubic potential well. Which of these systems exhibits degeneracy and explain why?	2	4	4
4A	The angular part of the 3D Schrodinger equation for a spherically symmetric potential is given by $$\sin\theta\frac{\partial}{\partial\theta}\left(\sin\theta\frac{\partial Y}{\partial\theta}\right) + \frac{\partial^2 Y}{\partial\phi^2} = l(l+1)\sin^2\theta\, Y\,.$$ Reduce the above equation to two 1-dimensional equations separately for θ and ϕ. Solve the resulting ϕ equation.	4	4	3

4B	Evaluate i) $[L^2\ , L_x]$ ii) $L_+|l,m\rangle$, where $|l,m\rangle$ is simultaneous eigenstate of L^2 and L_z.	4	5	5
4C	Construct the ground state wave function of the Hydrogen atom. Given: $$c_{j+1} = \frac{2\,(j+l+1-n)}{(j+1)(j+2l+2)}\,c_j$$ and $$Y_0^0 = \sqrt{\frac{1}{4\pi}}$$	2	4	4

5A	Consider an eigenket $|f\rangle$ of the angular momentum operator L_z. Prove that $L_\pm|f\rangle$ is also an eigenket of L_z.	5	5	4
5B	Using the matrix representations for the spin operators S_x and S_y, evaluate the commutator $[S_x\ , S_y]$.	3	5	5
5C	What are Clebsch–Gordan coefficients? Determine all possible states $|j,m\rangle$ that can be achieved by coupling two angular momenta $j_1 = 1$ and $j_2 = 1/2$.	2	5	2, 3

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